ROSE Compiler Infrastructure

Source-to-Source Analysis and Optimization

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Overview

- ROSE Compiler Infrastructure
- Research Objectives
  - General Optimization of existing applications
  - Optimization of High-Level Abstractions
    - Telescoping Language
    - Plus/Minus Languages
    - Many other names for this
  - Empirical Optimization
- Targets non-compiler audience
- Emphasis on whole program capabilities
- Open Source (EDG part as binary)
- Conclusions

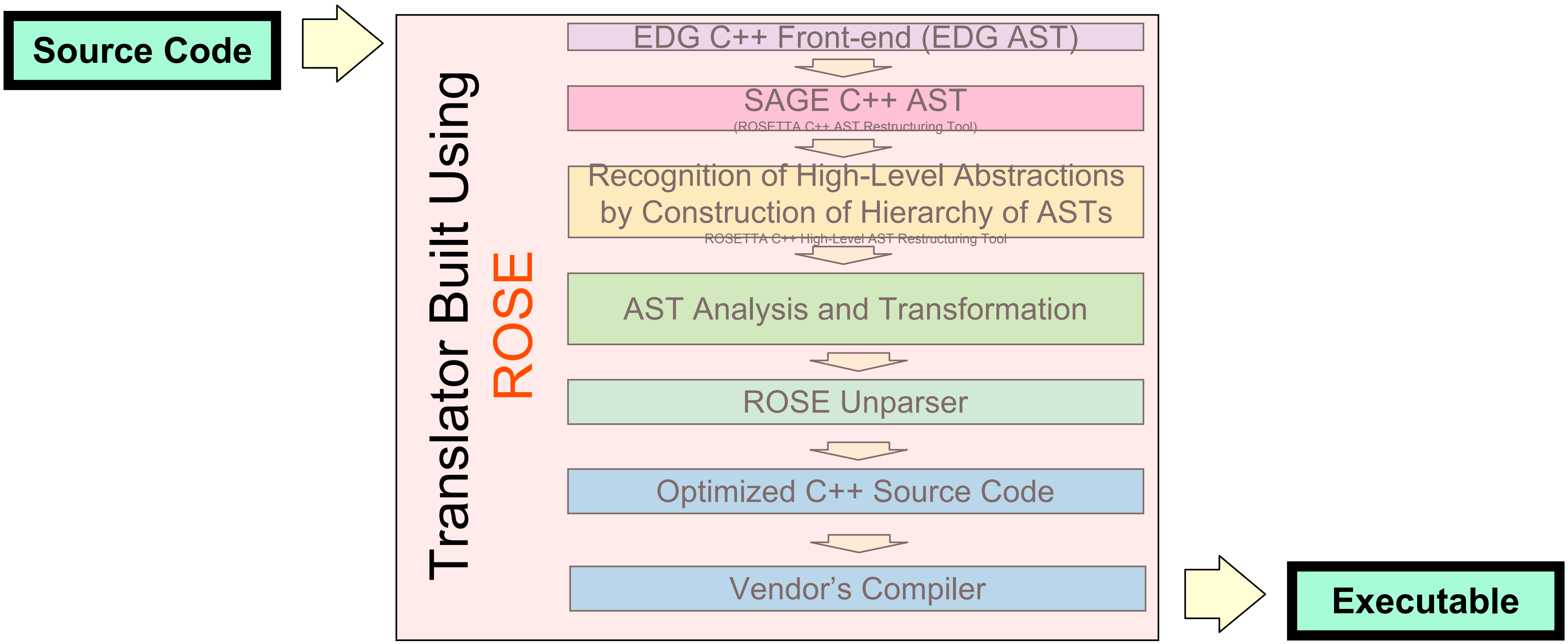
Motivation for Compiler Based Tools

- Current Status:
  - DOE generates huge amounts of software
  - ROSE provides a mechanism to automatically read, analyze, and fully rewrite ASC scale software in C, C++ (and eventually F90 as part of collaboration with Rice, we hope).
- ROSE Project focus IS on *optimization*

But a lot of tools could be built …,

Simple tools can only discover superficial things about software, to really know what is going on in an application you need a compiler infrastructure.

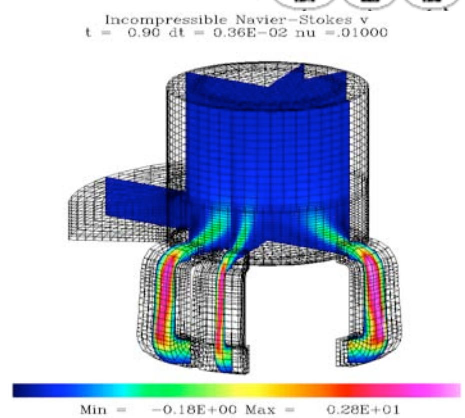
ROSE Source-to-Source Approach



- **ROSE Translator acts just like the vendor compiler**
- **Replaces compiler in application's *Makefile***

ROSE Project

- Software analysis and optimization for scientific applications
- Tool for building source-to-source translators
- Support for C and C++
- F90 in development
- Loop optimizations
- Lab and academic use
- Software engineering
- Performance analysis
- Domain-specific analys
- Development of new op
- Optimization of object-



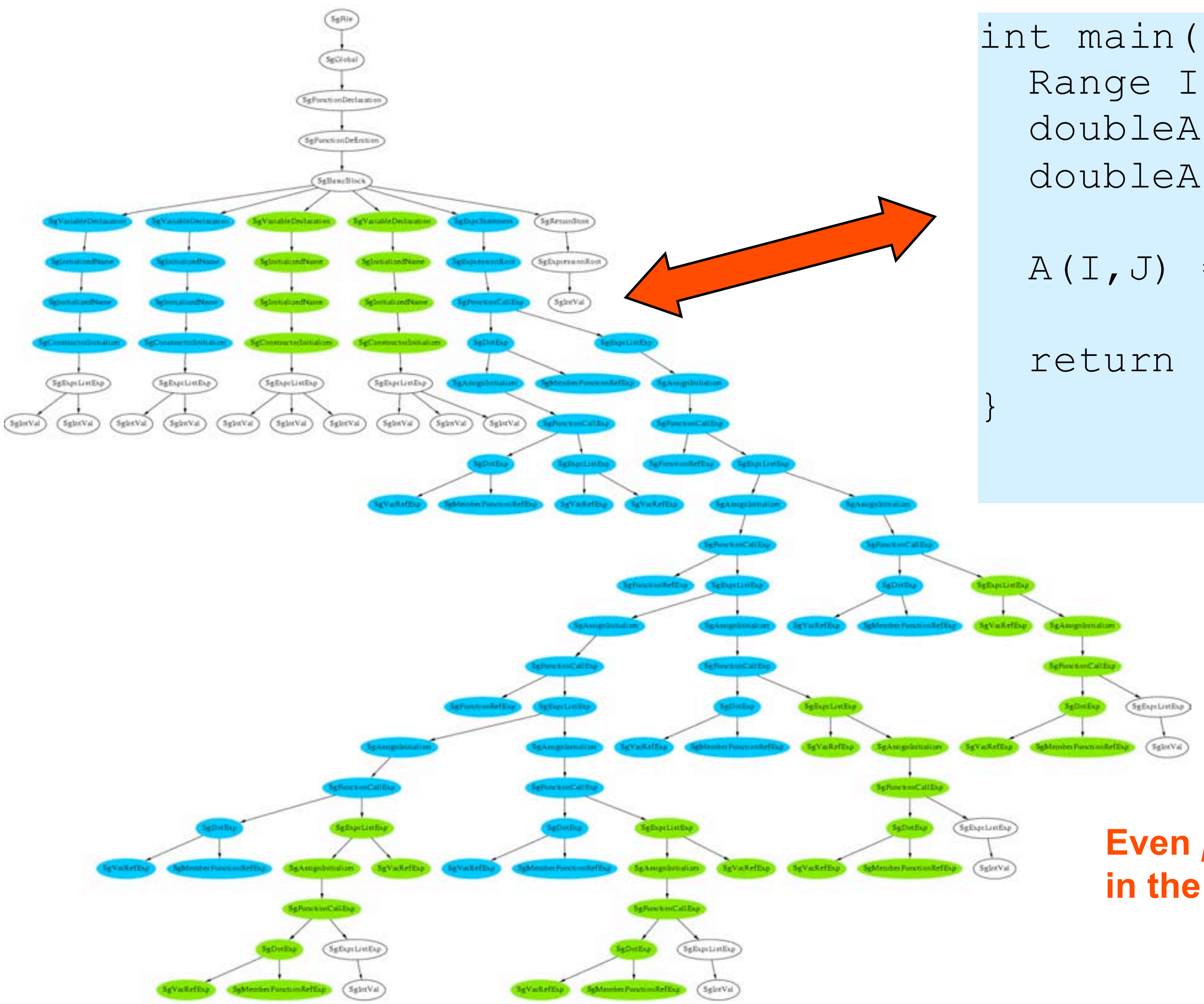
CASC

Program Analysis and Optimization

- Program Analysis (most are from Qing + contributions from students)
  - Call graph
    - Resolution of function pointers
    - Resolution of Virtual functions
    - Resolution of pointers to virtual functions
  - Dependence (procedural)
  - Control Flow (working on inter-procedural case)
  - Slicing (inter-procedural)
  - Partial Redundancy Elimination (PRE)
  - Connection to Open Analysis (work with ANL)
- Optimizations
  - Loop Optimization (Qing Yi)
    - Loop fusion, fission, blocking, unroling, array copy, etc.
    - inlining and outlining
  - Annotation Based Optimizations
  - Custom optimizations
    - Define your own optimization (high level or low level)

Automated Recognition

(Library Abstractions and other things)



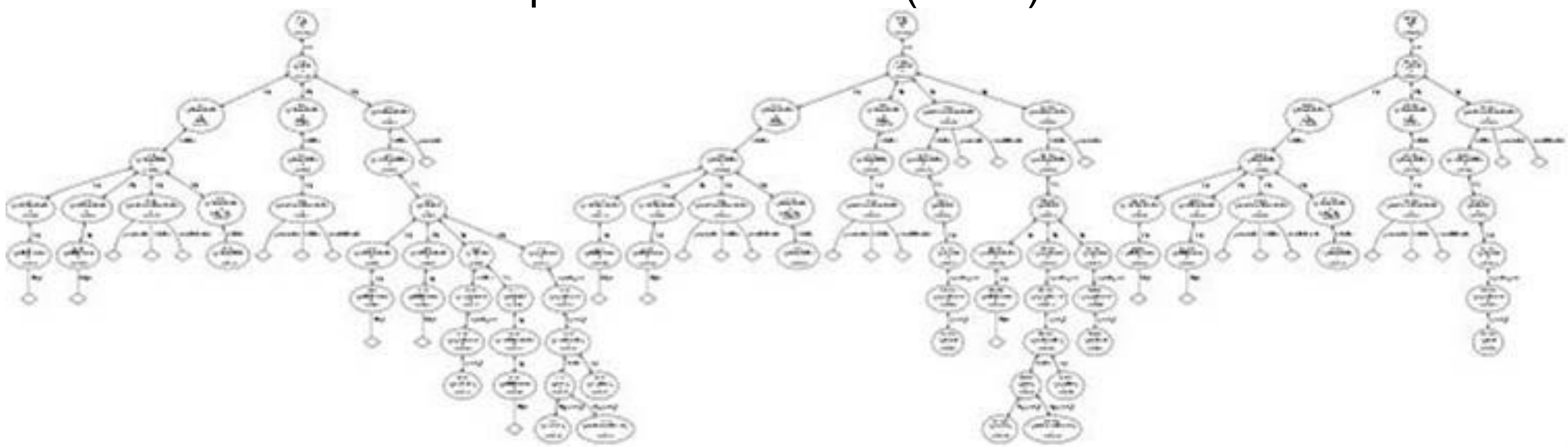
```
int main() {
  Range I(1,98,1),J(1,98,1);
  doubleArray A(100,100);
  doubleArray B(100,100);

  A(I,J) = B(I+1,J)+B(I-1,J)
          +B(I,J+1)+B(I,J-1);
  return 0;
}
```

Even *performance* information is in the AST (HPC Toolkit, RICE)

ROSE Whole Application Analysis

Three Separate source files (ASTs)



Supports Whole Program Analysis (Alternative to SQLite Interface)

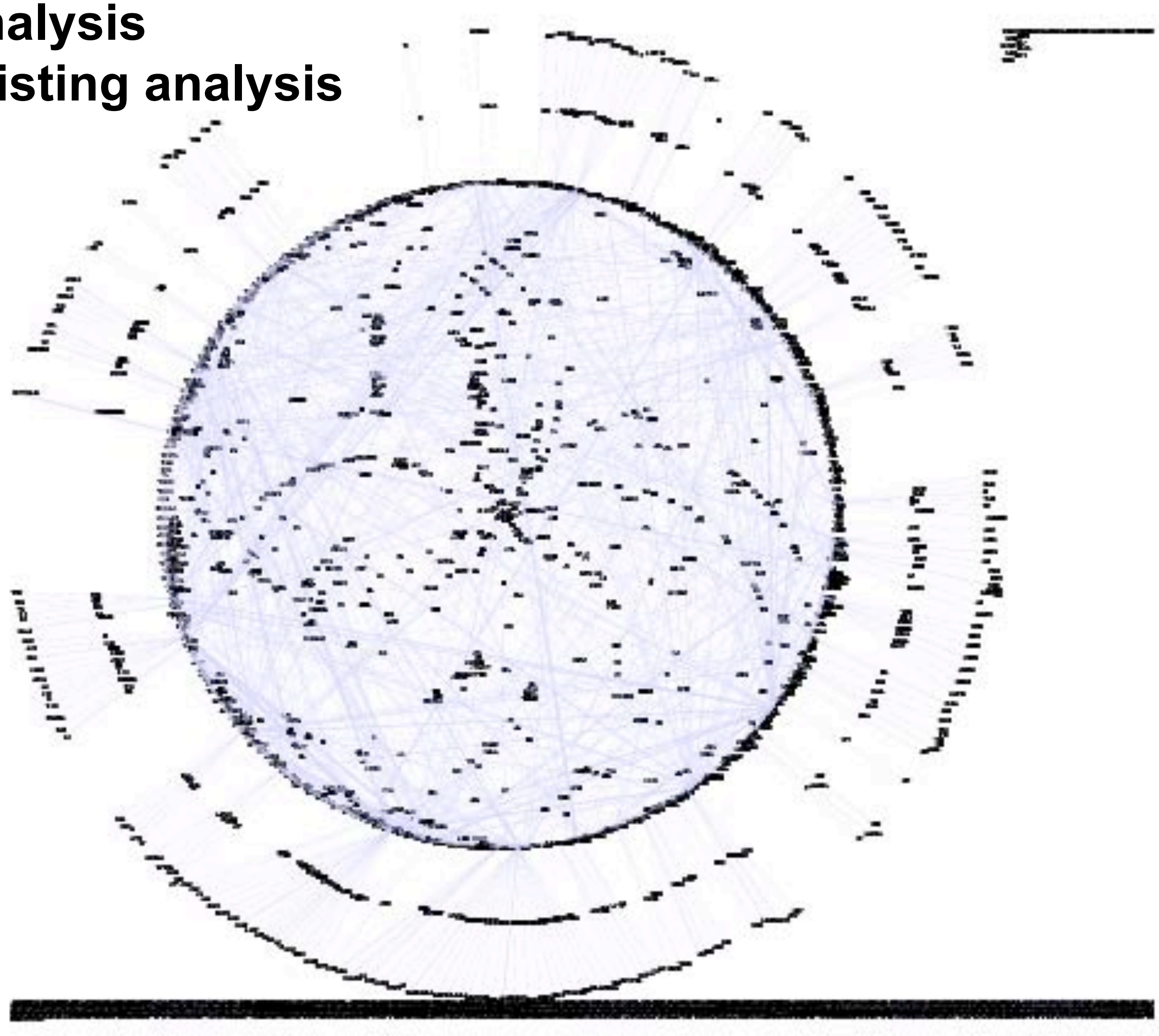
- **Shares AST nodes**
- **Preserves simplicity**
- **Preserves all analysis info**
- **Simple tools work on whole ASC applications**
- **Supports hundreds of source files**
- **Supports million line applications**

CASC

Merged ASTs save space and permit whole ASC scale application analysis

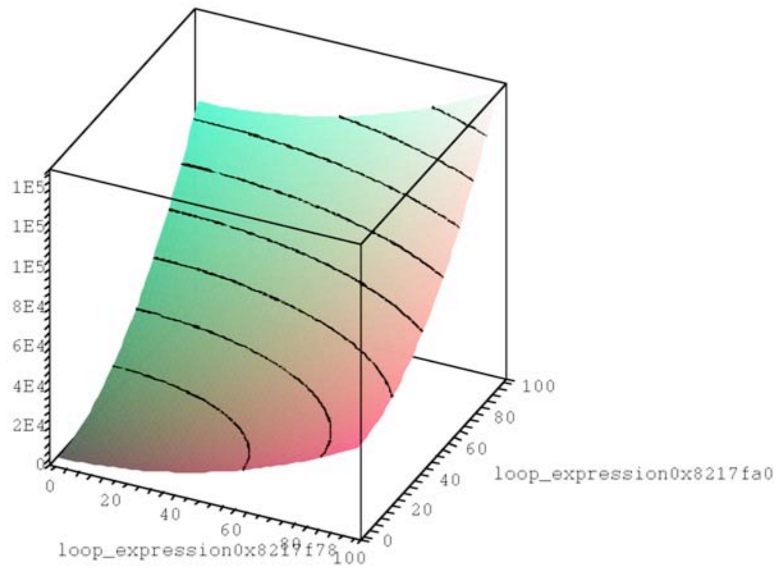
Large-Scale Application Support

- Call Graph Analysis
- Scaling up existing analysis

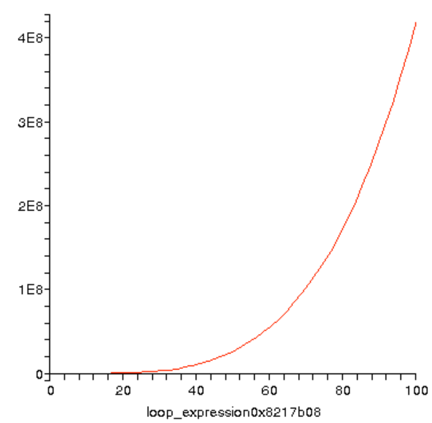


Automated Generation of Symbolic Equations for building Application Models

```
// Count -controlled loop complexity:
// 19+13*loop_expression0x8217f78+4*loop_expression0x8217f78^2+
//  19*loop_expression0x8217fa0+10*loop_expression0x8217fa0^2
int foobar( int bound1, int bound2   )
  {
   for (int i = 0; i < bound1; i++)
     {
      array[i] = 0;
      for (int j = 0; j < bound1; j++)
        {
         x = 0;
        }
     }
   for (int i = 0; i < bound2; i++)
     {
      array[i] = array[i  -1] + array[i+1] ;
      for (int j = 0; j < bound2;    j++)
        {
         x = 0;
        }
     }
   return x;
  }
```




```
// Count -controlled loop complexity:
// 8+13*loop_expression0x8217  f78^3+4*loop_expression0x8217f78^4   +
int main()
  {
   for (int i = 0; i < bound; i++)
     {
       array[i] = 0;
      for (int j = 0; j < bound; j++)
        {
         x = foobar( bound,bound  );
        }
     }
   return 0;
  }
```



Unparsed Example

Preserves formatting, comments, and preprocessor control structure

Original Input C++ Source code

```
#include "A++.h"
#include "../include/ROSE_TRANSFORMATION_SOURCE.h"
#include <iostream.h>

int main() {

  int x = 4;

  //these comments are difficult
  for (int i = 0; i < 10; i++) {
    while (x) {
      x = x + 1;

      if (false) { x++; x = 7+x; }
      else {
        x = x - 1;
        x--;
      }

      // comments!
      x++;
      x += 1;
    }
  }
  return 0;
}
```

Unparsed Output C++ Source code

```
#include "A++.h"
#include "../include/ROSE_TRANSFORMATION_SOURCE.h"
#include <iostream.h>

int main(){

  int x=4;

  //these comments are difficult
  for (int i=0; i < 10; i++){
    while(x){
      x = x + 1;

      if (false){ x++; x = 7 + x; }
      else {
        x = x - 1;
        x--;
      }

        // comments!
      x++;
      x += 1;
    }
  }
  return 0;
}
```

Interactions with Others

- DOE Laboratories:
  - LLNL (A-Div (Kull), B-Div (IRS), Mark Graff, TSTT, Overture, Babel)
  - ANL (Paul Hovland)
  - ORNL
- DOE Research Programs:
  - PERC (SLAC, TSTT, C/C++ Optimization, UT, ANL, Dyninst Binary Rewriting)
- Collaborations:
  - IBM Haifa (Shmuel Ur)
  - Texas A&M (Lawrence Rauchwerger, Bjarne Stroustrup)
  - Rice University (Ken Kennedy, John Mellnor-Crummey)
  - Vienna University of Technology (Markus Schordan)
  - University of Tennessee (Jack Dongarra's group)
  - Cornell University (Sally McKee, Brian White)
  - Indiana University (Andrew Lumsdaine, Jeremiah Willcock)
  - University of California at Berkeley (UPC, Kathy Yelick)
  - University of Oslo (Hans, Andreas, Are)
  - University of Maryland (Jeff Hollingsworth, Chadd Williams)
  - Friedrich-Alexander-University Erlangen-Nuremberg (Markus Kowarschik, Nils Thurey)
  - University of Texas at Austin (Calvin Lin)
  - USCD (Scott Baden)
  - London Imperial College (Olav Beckman, Paul Kelly)
  - UC Davis (Su, Bishop)